STUDY OF A COMPOSTING PROCESS IN THE GREEN WASTE PROCESSING PLANT

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ABSTRACT

Composting of sewage sludge together with green waste such as grass, leaves, branches, etc. is carried out in Poland in a number of facilities. A common problem of all compost plant operators is the selection of the type of composting technology and its modification to the conditions prevailing in a particular region. This is because the waste, the facilities are exposed to, differs and the technology must be adapted to the conditions prevailing in the given facility. In the field of technological research of the composting process, the research aims to characterize the conditions for composting organic waste in relation to the efficiency achieved, indication of the optimal technological parameters and assistance in the selection of the target composting technology. Waste composting technology is based on the appropriate selection of the composition of prisms and the periodic transfer of the prisms by means of a special turning machine. For the purpose of this research, hypotheses were formulated on the intensity of the composting process depending on the technological parameters of the prism (the size of the prism. the types of waste), the properties of the waste, and the intensity of aeration by turning. The results may be useful for compost plant operators and waste processing companies.

Keywords: composting, waste, sludge, microorganisms, stabilization, biodegradation.

1 INTRODUCTION

The research was carried out in the green waste treatment plant and sewage treatment plant Boguszowice owned by BEST - EKO company, located in Rybnik. Poland. There is a sludge and composting square within the plant, with an area of 16250 m^2, used for the composting process. Waste prisms can be placed in a hall or an external square. The composted waste consists of green waste (mainly grass and leaves), stabilized sewage sludge and ground shredded branches. The composting process begins with laying the right amount of waste on the square with the loader into a prism with a trapezoidal cross-section. After arranging the right amount of waste, the prism is turned, which, in addition to aeration, also allows better homogenization of the material. The freshly laid prism after being turned and a prism on the last day of intensive composting are shown in Figures 1 and 2. The composting process is divided into two phases: intensive composting and compost maturation. Composting time in aerated piles (intensive composting phase) lasts from 15 to 30 days. The prisms are aerated by means of a mobile turning machine (Figure 3). After the intensive composting process, waste from prisms is laid in the so-called monoprism up to a height of 5.5 m (compost maturation phase). The assumed time of compost maturation in prism is 45 days.

Volume LXV (2019). No. 1
p. 29 – 36. ISSN 1802-5420
DOI 10.35180/gse-2019-0003

Figure 1. Composting of waste in prisms - prism after transferring the first day of research.

Figure 2. Composting of waste in prisms - prism on the last day of the intensive composting process.

Volume LXV (2019). No. 1
p. 29 – 36. ISSN 1802-5420
DOI 10.35180/gse-2019-0003

Figure 3. A mobile turning machine.

During the experiment, the impact of waste mass, frequency of passing, ambient temperature and placement of prism for the tent hall or outside (weather conditions) on the temperature distribution, changes in the process gas concentration and the intensity of the composting process were examined. Six prisms were examined in detail during the experiment. The duration of testing each of the prisms was about 7 weeks.

The materials from which the prism was composed always consisted of grass (green waste), stabilized and drained sludge, and shredded branches. The volume ratio was the same each time and it was 4 parts of green waste, 2 parts of branches and 1 part of sludge.

According to the above, the following research hypotheses were formulated:

- The intensity of composting decreases with the increase of the cubic capacity (height) of the prism,
- The intensity of composting decreases with the decrease in the frequency of waste transfer,
- The intensity of composting decreases as a result of the application of organic waste.

2 METHODOLOGY

Measurements of gas emissions

Measurements were provided in field conditions. The tests of the aeration process were carried out using a probe made of acid steel, with holes at the end and a handle at the beginning. The probe included a plastic hose, through which the gas was sucked from the probe to the electrochemical analyzer from Kimo, Kigaz 200, and a thermocouple to measure the temperature of the tip of the probe.

Location of measurement points

Alongside the prism, measurements were made at 1/5, 2/5, 3/5, 4/5 lengths on both sides of the prism. Subject to differences in lengths of the prism, the places of measurement were determined each time for each newly created prism. Three measurements at different heights were made on each of the above-mentioned prisms. The measurement heights H were different depending on the size of the prism. The simulation of measurement points for the organic waste composting process was carried out based on the methodology developed by Mason [1].

3 MEASUREMENTS OF WASTE CHARACTERISTICS

As part of the research. samples of materials used to create a prism (grass, sewage, and ground branches). as well as samples from each of the prisms during the composting process were sampled. The test models were selected in accordance with the guidelines by Haug [2, 3] and Rosso et al. [4]. The following analyzes were carried out in the samples taken: humidity, loss on ignition, bulk density. AT_4 breathing activity according to Binner et al. [5].

Table 1. Basic technological parameters of prisms

Prisms	Creating the prisms	Closing the prism	Number of days of composting	Turning frequency	Prism localization
1	04.07.2017	22.08.2017	50	2 per a week	External
2	25.07.2017	12.09.2017	57	1 per week	External
3	22.08.2017	12.10.2017	52	No turning	Internal
4	20.09.2017	09.11.2017	52	No turning	External
5	19.10.2017	07.12.2017	50	1 per week	External
6	19.10.2017	07.12.2017	50	1 per week	Internal

Table 2. The mass of the prisms before and after the process

Prism	Material	Mass of component	Mass percentage	Mass of prism	Mass of prism after process	Mass reduction
		kg	% mass	kg	kg	%
1	Sludge	20220	28.5	70880	24320	65.7
	Grass (green waste)	28720	40.5			
	Shredded branches	21940	31.0			
2	Sludge	19600	23.9	81860	-	-
	Grass (green waste)	48540	59.3			
	Shredded branches	13720	16.8			
3	Sludge	19400	39.1	49580	35420	28.6
	Grass (green waste)	19740	39.8			
	Shredded branches	10440	21.1			
4	Sludge	6680	15.9	42030	39960	4.9
	Grass (green waste)	22550	53.7			
	Shredded branches	12800	30.5			
5	Sludge	6620	17.6	37520	34100	9.1
	Grass (green waste)	21220	56.6			
	Shredded branches	9680	25.8			
6	Sludge	6120	16.6	36960	39710	-7.4
	Grass (green waste)	20920	56.6			
	Shredded branches	9920	26.8			

4 WASTE CHARACTERISTICS

The sewage sludge in all prisms was characterized by a humidity content exceeding 70%, and showed an ignition loss of approx. 50% dry matter content (DMC). Wider differences were observed in the bulk density of

Volume LXV (2019). No. 1
p. 29 – 36. ISSN 1802-5420
DOI 10.35180/gse-2019-0003

sewage sludge, which ranged from 624 kg/m^3 to 889 kg/m^3. Sewage sludge applied to form the prisms revealed AT4 in the range of 20.6 mg O_2/g DMC up to 48.2 mg O_2/ g DMC.

Another component, grass similarly, as in the case of sewage sludge showed similar humidity values in each of the prisms from 36% to 55%. Ignition losses ranged from 47% DMC up to 59% DMC. There was a variety of bulk density for grass in each prism; the lowest value obtained was 194 kg/m^3, and the highest value was 470 kg/m^3. Significant differences were also noted in the AT4 grass value - the value was within 50.1 mg O_2/g DMC up to 83.8 mg O_2/g DMC.

Shredded branches showed humidity between 35% and 50%. Losses on ignition reached values from 53% DMC up to 70% DMC. The breathing activity of branches in prisms did not differ significantly and amounted on average to approx. 17 mg O_2/g DMC. The bulk density of this component varied, ranging from 265 kg/m^3 to 543 kg/m^3.

The sludge was characterized by nitrogen content from 1.9 to 3.1%, carbon from 18.2 to 29.6%, hydrogen from 2.8 to 4.6%, and sulphur from 0.7 to 1.2 %. The ground branches were characterized by low variability of nitrogen content ranging from 1.2 to 1.8%. The content of carbon and hydrogen decreased over time and amounted to 36% and 3.6% respectively.

The systematic decrease in the content of these elements resulted from the use of the same material for the formation of prisms. The sulphur content was variable and ranged from 0.15 to 0.25%.

The most variable material in terms of elemental composition was grass (green waste). The nitrogen content varied from 1.0 to 1.7%, carbon from 21.4 to 36.1%, hydrogen from 3.0 to 5.1%, and sulphur from 0.15 to 0.24%. The high variability within this group of waste resulted from the variability of the composition associated with the season (spring and summer, a larger share of grass, in the autumn a larger share of leaves and branches).

After mixing in the determined proportions of waste (volumetric grass, branches, sludge 4: 2: 1) waste samples were again collected and the elemental composition determined therein. Samples were also collected after the end of the process (about 50 days of the composting process). The test results carried out show that in all tested prisms the elemental composition on day 1 of the process was similar and ranged from 1.7 to 2.2% of total nitrogen, from 24.4 to 30.4% of carbon, from 3.1 to 4.0 % nitrogen, and from 0.28 to 0.46% sulphur. The ratio of carbon to nitrogen ranged from 11.3:1 to 17.5:1, which is below the optimal value for the composting process of 35:1 to 25:1.

The nitrogen content after the composting process in the part of the analyzed prisms decreased compared to the results obtained on the 1st day of the process. and in part of the prisms an increase in the nitrogen content was noted. The carbon content after the process ranged from 19 to 32%. In the case of carbon content in all heaps, a decrease in the content of this element was noted by several percent. The ratio of carbon to nitrogen decreased in all prisms and ranged from 11.2:1 to 14.8:1. The hydrogen content also decreased slightly in the majority of examined prisms. It ranged from 2.7 to 3.9% in the prism. The sulphur content remained at a similar level during the test.

Table 3. Physicochemical characteristics of materials used to compose prisms

Prism	Material	Humidity	Losses at ignition		AT_4		Bulk density
		(%)	(% DMC)	average	(mg O_2/g DMC)	average	(kg/m^3)
1/2	Sludge	73.83	49.13	49.57	48.51	48.20	624
			49.62		47.88		
			49.97				
	Grass (green waste)	51.89	47.21	47.73	61.09	65.96	194
			49.58		70.82		
			46.41				
	Shredded branches	35.30	69.30	70.49	15.98	18.34	265
			70.32		20.70		
			71.84				
3	Sludge	63.85	31.83	31.32	22.62	20.57	859
			31.96		18.52		
			30.16				

	Grass (green waste)	36.18	57.65	58.90	52.19	50.14	368
			59.98		48.08		
			59.08				
	Shredded branches	35.91	57.20	56.37	17.96	18.62	469
			57.42		19.27		
			54.49				
4	Sludge	76.24	55.62	53.84	61.68	59.86	757
			53.13		58.03		
			52.77				
	Grass (green waste)	58.89	47.12	46.98	75.18	64.61	470
			46.53		54.03		
			47.27				
	Shredded branched	56.52	54.12	53.43	25.19	33.80	543
			53.03		42.42		
			53.15				
5/6	Sludge	77.83	11.85	52.07	39.95	39.89	889
			12.27		39.83		
			11.51				
	Grass (green waste)	56.26	71.42	71.25	86.16	83.78	278
			70.83		81.39		
			71.49				
	Shredded branches	52.05	23.35	53.82	13.21	14.94	442
			24.12		16.68		
			23.32				

5 CHANGES IN TEMPERATURE DURING THE COMPOSTING PROCESS

A significant difference in the temperature of the prisms tested in the summer and autumn-winter season was noticed. The most favourable temperature distribution was shown by the first prism, tested in the summer season on the external square and turned twice a week. After the initial temperature of about 30ºC in the second week of testing, it increased to almost 60ºC. Such value lasted until about the 35th day of the process; then it gradually started to drop to around 46ºC, to finally increase by a few degrees in the last stage of the research (about 48ºC). The high temperature of the prism was also maintained due to the high ambient temperature, reaching an average of 23°C.

The second prism also located on the outside square in the summer differed in the frequency of turning (once a week). There were larger temperature fluctuations (close to 70ºC in the third week of testing, which could have a high outside temperature of 36ºC). In the initial stage of the process, it was about 65°C, then it gradually decreased by 50°C on day 30 to 40°C at the end of the analysis. It can be noticed that the temperature increases after the material has been turned.

The third prism was characterized by a lower temperature than the previous two prisms, which lasted for the most part at about 45ºC. One measurement deviated from this trend (about 59°C in the second week), followed by a lowering of the outside temperature from approx. 20°C to 14°C. The lower ambient temperature was maintained until the end of the prism measurements, which could affect the temperature of the material. Its relatively constant level can also be explained by the location of the prism in the roofed hall, where it was not exposed to sunlight and the lack of turning.

Prism 4 showed an initial temperature of 43°C; then it rose to about 65°C in the second week of the process, then gradually dropped down to 21°C in the final stage of the research. This decrease can be explained by the non-passing of material and lower ambient temperature (autumn season, external square).

The temperature in prisms 5 and 6 was similar: initially, these prisms showed a temperature at 52°C (5) and 60°C (6), which lasted until about the 9th day of the process. Subsequently, these temperatures dropped sharply to around 30°C, so that later, with slight fluctuations caused by material transfer, the level would reach several degrees. The time of year had an impact on it; a sharp drop in temperature after day 9 of the process was probably caused by the lowering of the outside temperature from 13.5°C to 4.5°C.

Table 4. Changes in temperature during the process

Prism	The day of the maximum temperature occurrence	Maximum temperature	Final temperature
1	14	62 °C	48 °C
2	22	68 °C	28 °C
3	9	58 °C	38 °C
4	8	58 °C	22 °C
5	8	55 °C	18 °C
6	9	60 °C	15 °C

6 CHANGES IN GAS CONCENTRATIONS IN COMPOST PRISMS

Concentration of O_2

The biggest fluctuations can be observed in the case of prisms turned in the summer season. In both of them, the oxygen level decreased until the moment of turning, after which it increased and dropped again until the next transfer. The lowest value of oxygen concentration for prism 1 was recorded in the fifth week of testing (about 7%), in the case of the second prism and in the 3rd week (6%). A relatively constant level of oxygen concentration close to 20% was observed in the 3rd (non-turned) prism, which however did not translate into the results obtained for the second of the non-turned prisms. Prisms 5 and 6, despite being turned once a week, did not show significant changes in O_2 concentration (about 19%).

Concentration of CO

Its increased concentration was observed only in prisms 1 and 2, the next ones did not show a significant share of CO. For prism 1, the maximum concentration was about 110 ppm at the beginning of the process, in the case of 2 - about 82 ppm in the 3rd week of testing.

Concentration of CO_2

Similarly, to the previous parameter, also here the largest fluctuations were in the case of prisms 1 and 2, the increase in CO_2 concentration occurred in prisms 2 immediately after turning. The maximum concentration for both prisms was approx. 13%. The minimum values were reached in the 6th week of the process in the prism 1 (1% CO_2) and in the 5th week for prism 2 (0.5% CO_2). The lowest level of carbon dioxide concentration was recorded in case of prism 3. Initially it was 6%, then it dropped and remained relatively constant (about 1%) except on the 35th day of the process, when this concentration increased to about 3%. Prism 4 showed two points of increase in CO_2 concentration: 8% in the first week of the process and 6% in the 4th week. At the final stage of the research, it was characterized by a carbon dioxide concentration of approx. 3%. There was an initial increase in the concentration of carbon dioxide in the heaps of 5 (5%) and 6 (8%). Both of them had a relatively constant and similar level of carbon dioxide concentration (about 2%).

Concentration of NO

In prism 1 after the initial NO concentration at the level of approx. 22 ppm, its decrease was noted to the value close to 1 ppm, which was maintained with slight fluctuations during most of the process, to finally reach the level of approx. 4 ppm. The largest fluctuations of this parameter were observed in the case of the second and third prisms. Both of them were characterized by an initial low concentration of NO (about 1 ppm), which increased in the final stages of the process. In the case of prism 2, the highest value was recorded on the 43th day of the process and it amounted to approx. 22 ppm, while for the prism 3 it was 33 ppm on day 35. However, the final concentration in prism 2 was lower and amounted to approx. 1 ppm, while in prism 3 it was 22 ppm. Prism 4 was characterized by NO concentration of approx. 5 ppm (except for a significant decrease to 0 ppm in the 3rd week of the process and an increase to 10 ppm on day 29 of the study). Prisms 5 and 6 showed a similar course of nitric oxide concentration in the material. After forming the prisms, it was about 9 ppm. then the concentration dropped to about 1 ppm, which persisted until the end of the process.

Table 5. Changes in the concentration of gases in the prism during the composting process

Prism	O_2 [%]			CO [ppm]			CO_2 [%]			NO [ppm]		
	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min
1	14	19	7	22	110	0	7	13	1	5	22	1
2	13	19	6	15	82	0	6	13	0.5	4	22	1
3	19	21	14	5	71	0	2	6	1	8	33	2
4	17	21	12	3	29	0	3	8	3	5	10	0
5	18	20	15	2	20	0	3	5	2	3	9	0
6	19	21	13	2	36	0	2	8	2	2	9	0

7 DISCUSSION

Referring to the research hypotheses submitted at the beginning of this article, I can state that the intensity of composting decreases with the increase of the volume of the prism, and in particular, it is related to the height of the prism. For the height of the prism above 2 meters, there is a visible reduction in the natural draft of the air and, therefore, a slowdown in the composting intensity is observed. It is directly related with the second hypothesis. The frequency of aeration is related to the oxygen conditions prevailing in the heap, when the height of the prism is lower than 2 meters, the frequency of its turning can be limited to 1 per week. It is enough to turn a low prism twice, first time during construction and second after a week; no further aeration is required due to auto aeration process. For heights exceeding 2 meters, the aeration frequency should be increased accordingly. The size of the prisms should be designed so that the surface to volume ratio does not exceed 2.5. The feedstock in which the decomposition has already started has a much greater demand for oxygen, especially in the first phase of the process. Another important element is the structure of the material used to form a prism, the mixed material must have a structure that allows the formation of air spaces inside the prism. The porosity of the material allows the natural movement of gases and thus the self-aeration of the heap.

8 CONCLUSION

The research revealed that the oxygen conditions in the prisms were positive regardless of the technological regime applied. The low intensity of turning, placement of prisms in the hall and relatively low outside temperatures (at a high ratio of area to volume of prisms) caused cooling of the prisms and low efficiency of water removal. In the prisms where the temperature was above 50 ° C for several weeks, high dynamics of the decrease in breathing activity was observed, as a result of the deepening stabilization of organic matter. Temperatures obtained in the study may not be sufficient to achieve complete hygienization of compost and weed seed inhibition. It was found that the necessary technological activity is to carry out the turning of waste in prisms with an average frequency at least once a week. A higher frequency is not required unless an oxygen deficit is found in the prisms (concentration <7%). The mixture of waste components should be prepared in such a way that the final initial humidity ranges from 50 to 60%. The size of the prism should be designed so that the surface to volume ratio does not exceed 2.5. In autumn and early spring, at low ambient temperatures. in order to maintain good thermal conditions in the heap, the heaps should be constructed to allow the surface to volume ratio to be below 2.

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